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ECONOMIC IMPACT AND REGULATORY FLEXIBILITY ANALYSIS OF PROPOSED EFFLUENT GUIDELINES AND NESHAP FOR THE PULP, PAPER, AND PAPERBOARD INDUSTRY

FINAL REPORT

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3.3 MARKET IMPACT ANALYSIS METHODOLOGY

Implementing regulations to control air and water pollutants from pulp and paper manufacturers will affect the costs of production in the U.S. pulp and paper industry. The costs of the regulations will vary across the many different mills in the industry, depending on the production processes currently employed. Mill-level production responses to these additional costs will determine the market impacts of the regulations. Specifically, the cost of the regulations may induce some mills, or product lines within mills, to close or to change their current level of production. These choices affect, and in turn are affected by, the market price for market pulp, paper, and paperboard products.

A variety of approaches may be used to quantify and evaluate economic impacts; they reflect a variety of underlying paradigms. The market impact model applies standard microeconomics concepts to model the supply of pulp, paper, and paperboard products and the impacts of the regulations on production costs and facility output decisions. The three main elements of the analysis are regulatory effects on the manufacturing facility, market responses, and facility-market interactions. For a more comprehensive and technically detailed discussion of the market impact analysis methodology and model, please see Appendix A of this report.

3.3.1 Market Impact Model Concepts

3.3.1.1 Facility-Level Effects

At any point in time, the costs that a firm faces can be classified as either unavoidable (sunk) or avoidable. In the former category, we include costs to which the firm is committed and that must be paid regardless of any future actions of the firm. The second category, avoidable costs, describes any costs that are foregone by ceasing production. These costs can be further refined to distinguish between costs that vary with the level of production and those that are independent of the production level. For example, production factors such as labor, materials, and capital (except in the short run) vary with the level of output, whereas expenditures for facility security and administration may be independent of production levels but avoidable if the facility closes down.

Figure 3-6 illustrates the derivation of a facility supply function for a market pulp, paper, or paperboard product from the classical U-shaped structure of production costs with respect to output. The horizontal axis, q/t, represents output per period and the vertical axis, \$/q, represents the cost per unit of output. Let AVAC be the facility's average variable (avoidable) cost curve and ATAC the average (avoidable) cost curve for producing the product. The vertical distance between ATAC and AVAC is the per-unit average cost of nonvariable avoidable costs, and it approaches zero as the number of units of output increases. MC is the marginal cost of producing paper, paperboard, or market pulp, which intersects AVAC and ATAC at their respective minimum points. All these curves are conditional on input prices and the technology in place at the facility.

The facility supply function is the section of the marginal cost curve bounded by the quantities q^m and q^M. q^M is the largest feasible production rate that can be sustained at the facility given the technology and other fixed factors in place, regardless of the output price. Quantity q^m is the minimum economically feasible production rate determined by the minimum of the AVAC curve, which coincides with the price p^m. Suppose the market price of paper is less than p^m. In this case, the firm's best response is to close the facility and not produce paper because $P < AVAC$ implies that total revenue would be less than variable costs if the facility operated at the associated output levels below q^m.

Now consider the effect of the proposed regulatory control costs. These control costs fall into one of two categories: avoidable variable and avoidable nonvariable. We characterized these proposed costs as avoidable because a firm can choose to cease operation of the facility and thus avoid incurring the costs of compliance. The variable control costs include the O&M costs of the controls, and the nonvariable costs include compliance capital equipment.

The effect of these additional costs is illustrated in Figure 3-7. The facility's AVAC and MC curves shift upward (to AVAC′ and MC′) by the per-unit variable compliance costs. In addition, the nonvariable compliance costs increase total avoidable costs and thus the vertical

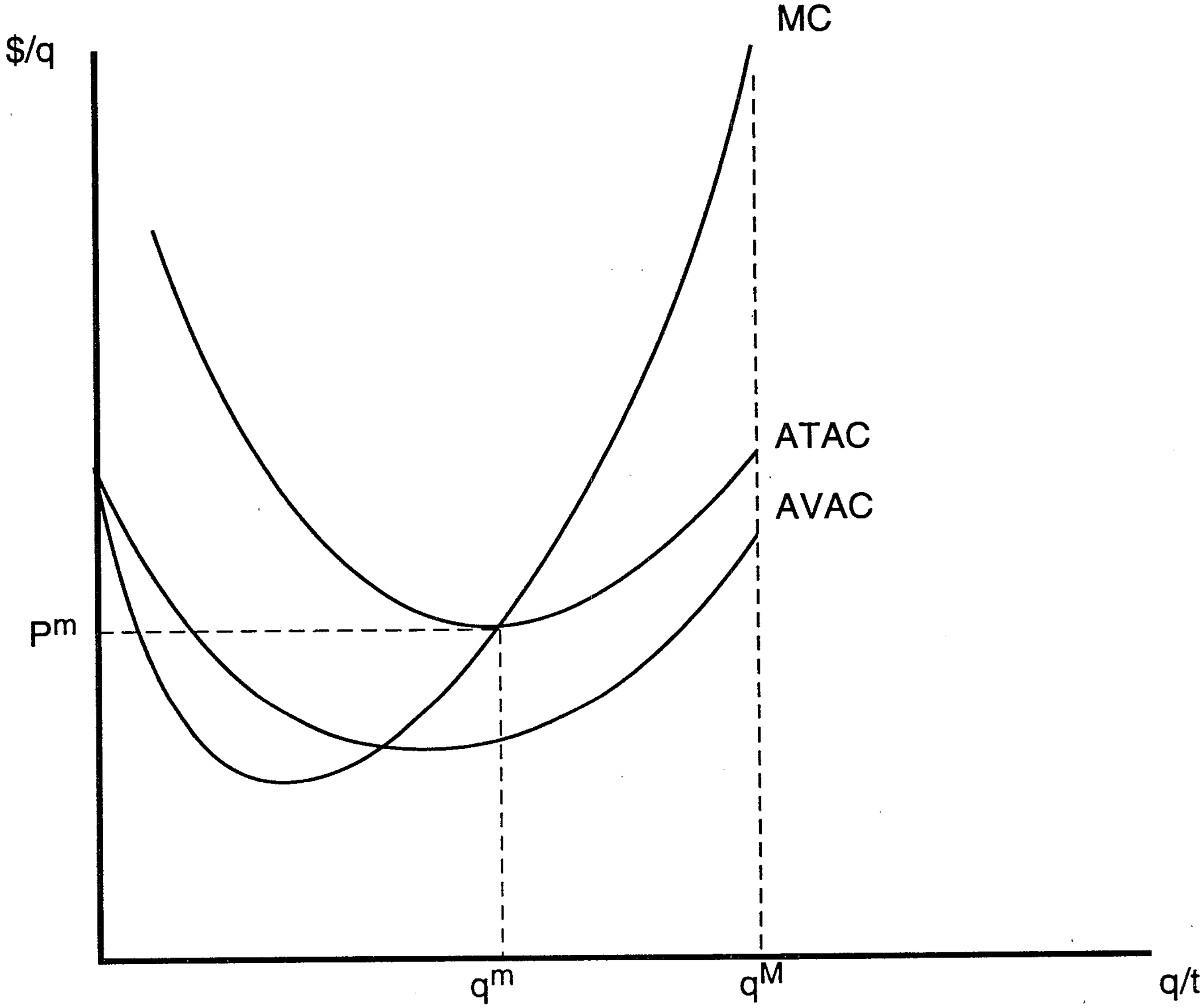


Figure 3-6. Facility cost curves.

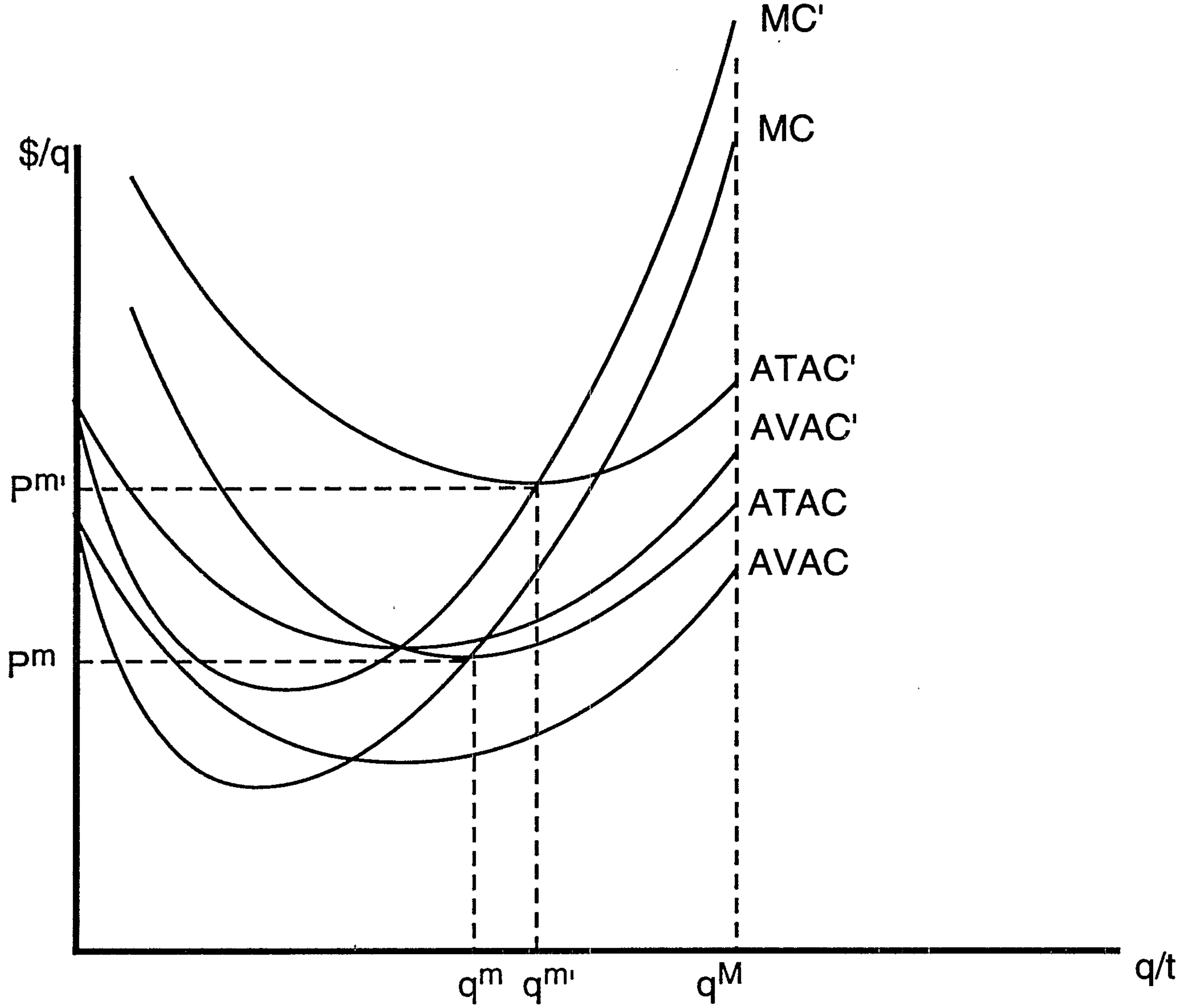


Figure 3-7. Effect of compliance costs on facility supply function.

distance between ATAC′ and AVAC′. The facility's supply curve shifts upward with marginal costs, and the new (higher) minimum operating level ($q^{m\prime}$) is determined by a new (higher) $p^{m\prime}$.

Now consider the effect of compliance costs on the derived demand for inputs at the regulated facility. Paper and paperboard manufacturing facilities are market demanders of pulp. We can employ a similar neoclassical analysis to the one above to demonstrate the effect of compliance costs on the demand for the market pulp input. Figure 3-8 illustrates the paper and paperboard manufacturing facility demand function for market pulp. Each point on the derived demand curve equals the firm's maximum willingness to pay for the corresponding marginal input. This is typically referred to as the input's value of marginal product (VMP), which is equal to the price of the output (P) less the per-unit compliance costs (c) times the input's "marginal physical product" (MPP), which is the incremental output attributable to the incremental input. Ignoring any effect on the output price for now, an increase in per-unit compliance costs due to the regulations will lower the VMP of all inputs by the unit amount of the additional compliance costs, leading to a downward shift in the derived demand curve in section a of Figure 3-8 from D_y to D'_y.

The paper and paperboard manufacturing facility demand curve for market pulp is downward sloping in this example, indicating that the marginal physical product of market pulp diminishes as more is used to produce paper and paperboard, and substitution possibilities exist with other inputs. This model assumes that the input-output relationship between the market pulp and the final paper and paperboard product is strictly fixed, not only by product specification but also by constant efficiency of use at all input levels. Therefore, the VMP of the market pulp is constant and the derived demand curve is horizontal with the constant VMP as the vertical intercept, as shown in section b of Figure 3-8.

3.3.1.2 Market-Level Effects

Consider the relationship depicted in Figure 3-9 between the markets for a single paper or paperboard product, Q_x, and a market pulp input, Q_y. Q_y, along with other inputs, such as labor, energy, and chemicals, is used in the production of Q_x. We assume that prices for the

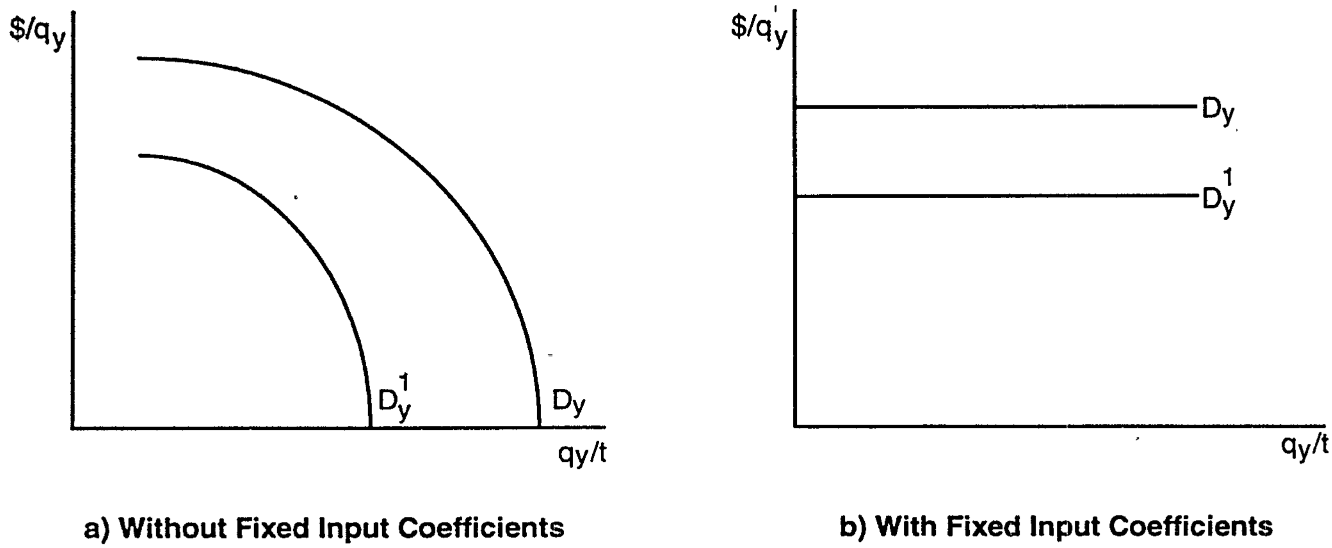
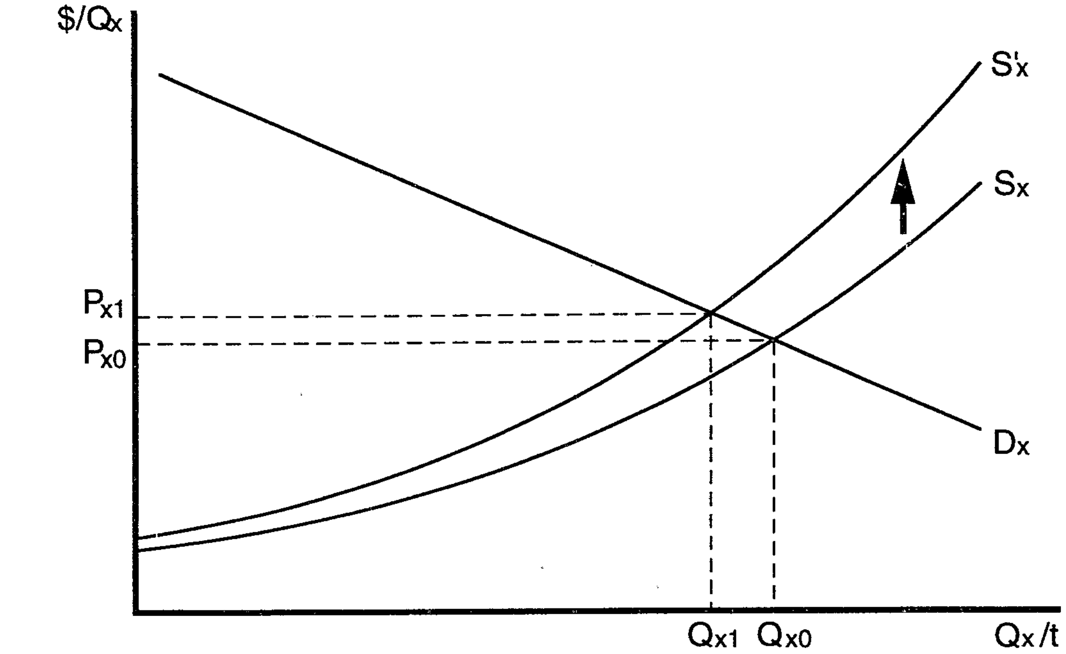
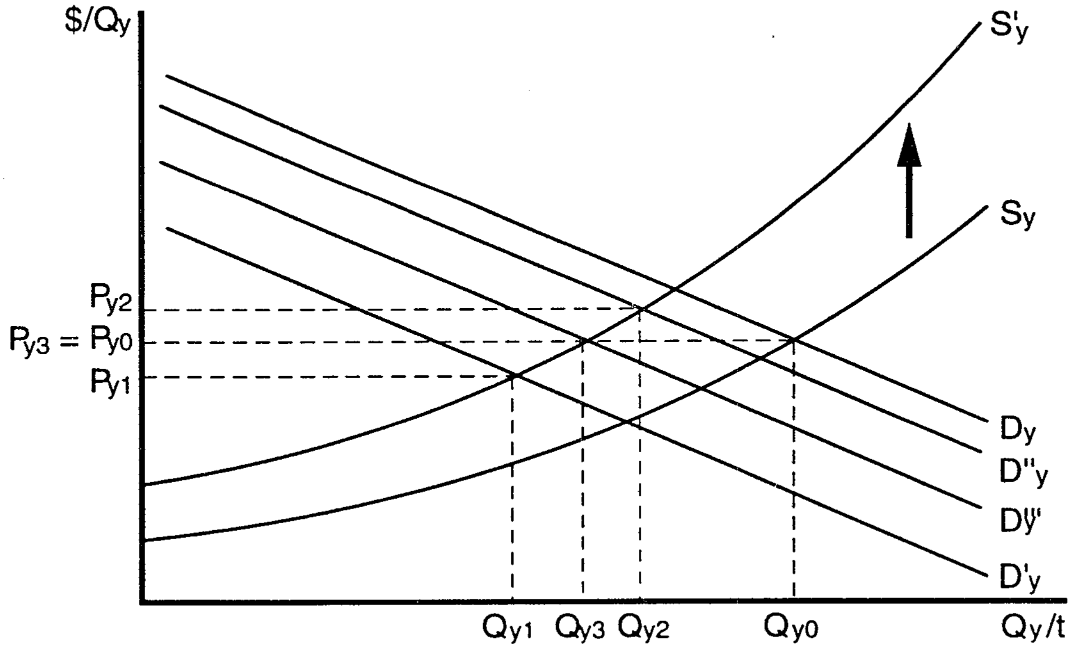


Figure 3-8. Effect of compliance costs on derived demand for market pulp at regulated facility.



(a) Market for Paper or Paperboard Product, Q_x



(b) Market for Pulp, Q_y

Figure 3-9. Market equilibria with and without compliance costs.

respective commodities are determined in competitive markets (i.e., individual facilities have negligible power over the market price of the commodities and thus take the price as "given" by the market). Under perfect competition, market prices and quantities are determined by the intersection of market supply and demand curves. A market supply curve is the sum of all facility supply curves, and a market demand curve is the sum of the demand curves for all demanders of the commodity. The demanders of paper or paperboard product, Q_x, are final product consumers, and the demanders of market pulp, Q_y, are the individual facilities that purchase market pulp for producing paper and paperboard products. Without the proposed compliance costs, the market quantity and price of paper or paperboard product, Q_x (Q_{x0}, P_{x0}), are determined by the intersection of the market demand curve (D_x) and the market supply curve (S_x), and the market quantity and price of market pulp, Q_y (Q_{y0}, P_{y0}), are determined by the intersection of the market demand curve (D_y) and market supply curve (S_y).

Imposing the regulations increases the costs of producing pulp and, thus, paper and paperboard, shifting the market supply function for both commodities upward to S'_x and S'_y, respectively. The supply shift in the market for paper and paperboard products causes the market quantity of each to fall to Q_{x1} and the market price to rise to P_{x1} in the new equilibrium. In the market for pulp, the drop in the market quantity is unambiguous; however, the direction of the change in the market price can only be determined if we know the relative magnitudes of the demand and supply shifts. If the downward demand effect dominates, the price will fall (e.g., P_{y1}); if the upward supply effect dominates, the price will rise (e.g., P_{y2}); and if the effects just offset each other, the price remains unchanged (e.g., $P_{y3} = P_{y0}$).

The sign (positive or negative) of the effect of these market adjustments on commodity prices and quantities is summarized in Figure 3-10; the magnitude of these effects is estimated by the market impact model. The supply shifts for market pulp, paper, and paperboard cause the market price to rise and market quantity to fall for these commodities at the new equilibrium. However, the downward shift in the demand curve for market pulp will have an offsetting effect on price, leaving the total effect ambiguous, while exacerbating the effect on quantity, resulting in an even lower quantity produced. In both cases, the producers that are unaffected by the regulations receive the higher price for their products without the associated increase in compliance costs and thus increase their production levels.

		Quantity	
		Increase	Decrease
Price	Increase	Yes	Yes
	Decrease	Yes	Yes

a) Market Pulp

		Quantity	
		Increase	Decrease
Price	Increase	No	Yes
	Decrease	Yes	No

b) Paper and Paperboard Products

Figure 3-10. Market adjustments for market pulp, paper, and paperboard products.

3.3.1.3 Facility-Level Response to Control Costs and New Market Prices

In evaluating the market effects for pulp, paper, and paperboard products, we must distinguish between the initial effect of the regulations and the net effect after all markets have adjusted. Initially all affected facilities' supply curves for market pulp, paper, and paperboard shift upward by the unit variable costs of the regulation. As a result, all affected facilities' derived demand curves for market pulp shift downward by the unit variable control costs. However, the upward shift in the industry supply curves for paper and paperboard pushes up the prices of those commodities, which subsequently raises the VMP of the market pulp and, thus, puts upward pressure on the derived demand for that commodity. In general, the initial upward shift in supply at the facility will be greater than the subsequent increase in market price so that the mill reduces supply of market pulp, paper, or paperboard. The initial downward shift in demand will typically dominate the subsequent upward shift so that the net shift is downward and the mill reduces demand for market pulp. However, determining which shift dominates for a particular mill is difficult: it depends on the relative magnitude of the facility-specific unit variable costs of the regulation and the changes in market prices.

Given changes in market prices and costs, mills will elect to either:

- Continue to operate, adjusting production and input use based on new revenues and costs, or
- Close the facility if expected revenues do not exceed total avoidable costs.

This decision can be extended to the multiproduct facility where product lines may be closed if product revenues are less than product-specific avoidable costs, and the entire facility may be closed if total expected revenues from all products (market pulp, paper, and paperboard) do not exceed facility-specific avoidable costs.

This approach to modeling the facility closure decision is based on conventional microeconomic theory. It compares the ATAC—which includes all cost components that fall to zero when production discontinues—to the expected postregulatory price. Figure 3-7 illustrates this comparison. If price falls below the ATAC, total revenue would be less than the total avoidable costs. In this situation, the owner's cost-minimizing response is to cease production.

An additional aspect of the facility-level impacts is the quantity adjustments. Changes in costs will change producers' output rates. However, some of this effect is mitigated when prices are increased. Of course, facility and product-line closures directly translate into quantity reductions. However, the output of operating facilities also will change as will supply from foreign sources. Affected facilities that continue to produce may increase or decrease their output levels depending on the relative magnitude of the unit variable control costs and the changes in market prices. Unaffected facilities will not face an upward shift in their product supply curves, so their response to higher product prices is to increase production. This response is illustrated in Figure 3-11 as an upward movement along the facility's supply curve for the product. Foreign producers, which do not incur higher production costs because of the regulations, will respond in the same manner as these unaffected U.S. mills.

3.3.2 Operationalizing the Market Impact Model

To estimate the economic impacts of the regulations, we operationalized the competitive market model of the pulp and paper industry outlined in the previous subsections. The model incorporates the facility-specific information on production obtained from the EPA's *1990 National Census of Pulp, Paper, and Paperboard Manufacturing Facilities* (EPA, 1991) and model parameters characterizing domestic and foreign (export) demands as well as foreign supply (imports). The model incorporates these data sources to provide an empirical characterization of the U.S. pulp and paper industry and product markets for a base year of 1989. We chose this base year of analysis because it is the last year for which facility-specific production and technical data were available from the *National Census* (EPA, 1991) and for which supporting economic data were readily available.

The model analyzes market adjustments for 31 paper and paperboard product markets and 6 market pulps by employing a process of *tatonnement* whereby prices approach equilibrium through successive correction—modeled as a Walrasian auctioneer. Integrated facilities and

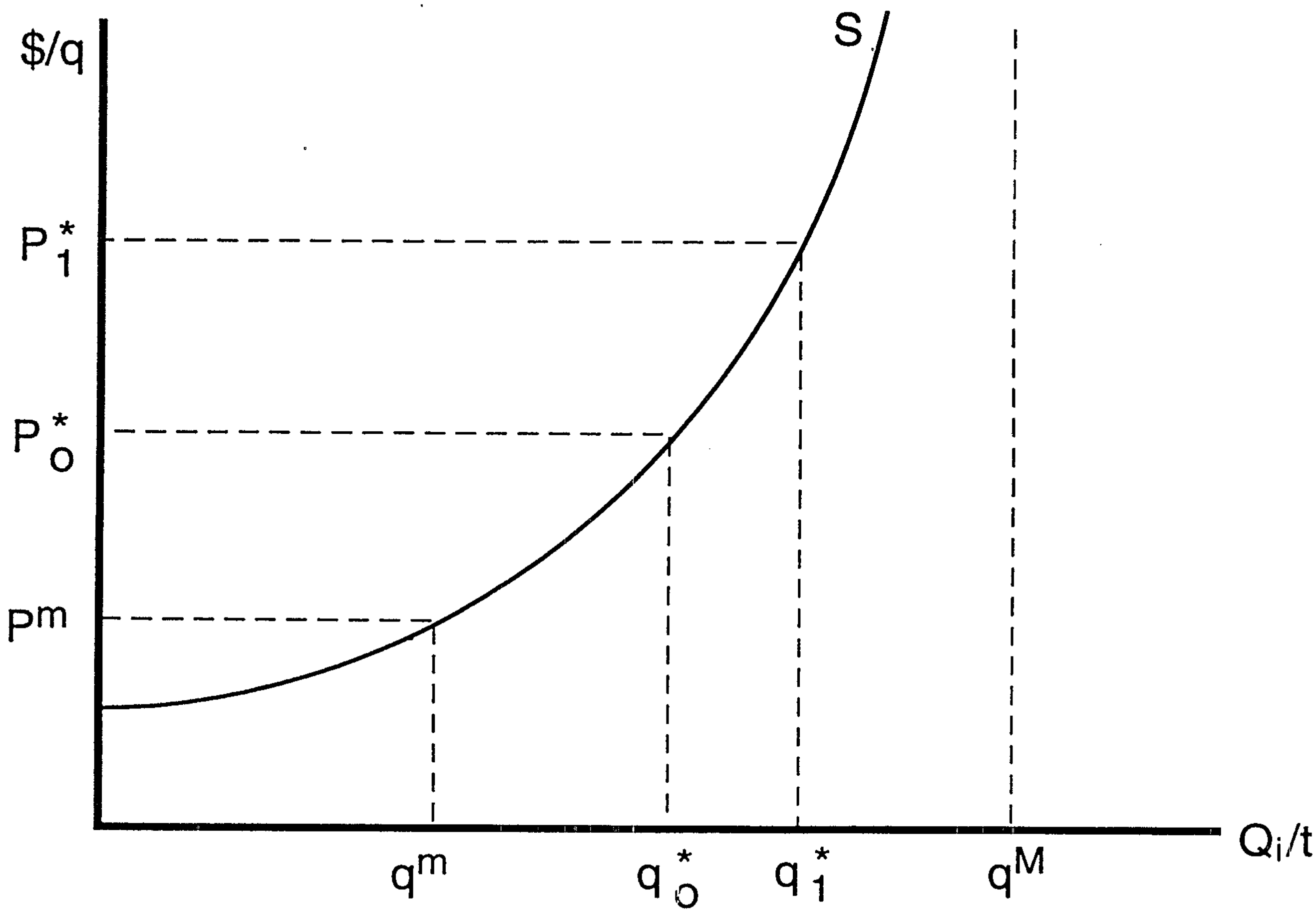


Figure 3-11. Movement along the product supply function.

paper-making facilities constitute those facilities supplying final paper products; the pulp mills and those integrated mills involved in the market for pulp, either as a supplier or demander, constitute those facilities included in the model for market pulps. The model also includes a foreign trade sector with which to assess the impact of international trade responses on market outcomes and vice versa.

To implement this model, we identified commodities and facilities to be included in the analysis, specified the supply and demand side of the market and associated response parameters, specified the foreign trade sector and provided the corresponding response parameters, incorporated demand and supply specifications into a market model framework, and evaluated market adjustments due to imposing regulatory compliance costs and estimated the impacts.

3.3.2.1 Model Dimensions

Clearly the analysis must account for all marketable commodities involved in producing pulp and paper, as well as all suppliers of these commodities. Figure 3-12 illustrates the modeled interactions between commodities and producers. The first marketable product is pulp, either bleached or unbleached; the second marketable product is the final paper or paperboard product. The model analyzes the market adjustments for 6 market pulps and 31 paper and paperboard products. All of these products are consumed and produced domestically, as well as traded internationally. Therefore, domestic producers export some pulp and paper products to other countries, and foreign producers supply their products to U.S. markets.

The pulp and paper industry is characterized by both nonintegrated and vertically integrated mills. Nonintegrated mills include pulp mills that produce market pulp as well as paper mills that purchase market pulp to produce paper and paperboard products. Vertically integrated mills rely mostly on their own production of pulp to produce paper and paperboard products. Those vertically integrated mills without enough internally produced pulp are also demanders of market pulp, and those that produce an excess supply of pulp are suppliers of market pulp. We modeled the production from 566 pulp, paper, and paperboard manufacturing facilities, including 28 pulp mills, 303 paper mills, and 235 integrated mills.

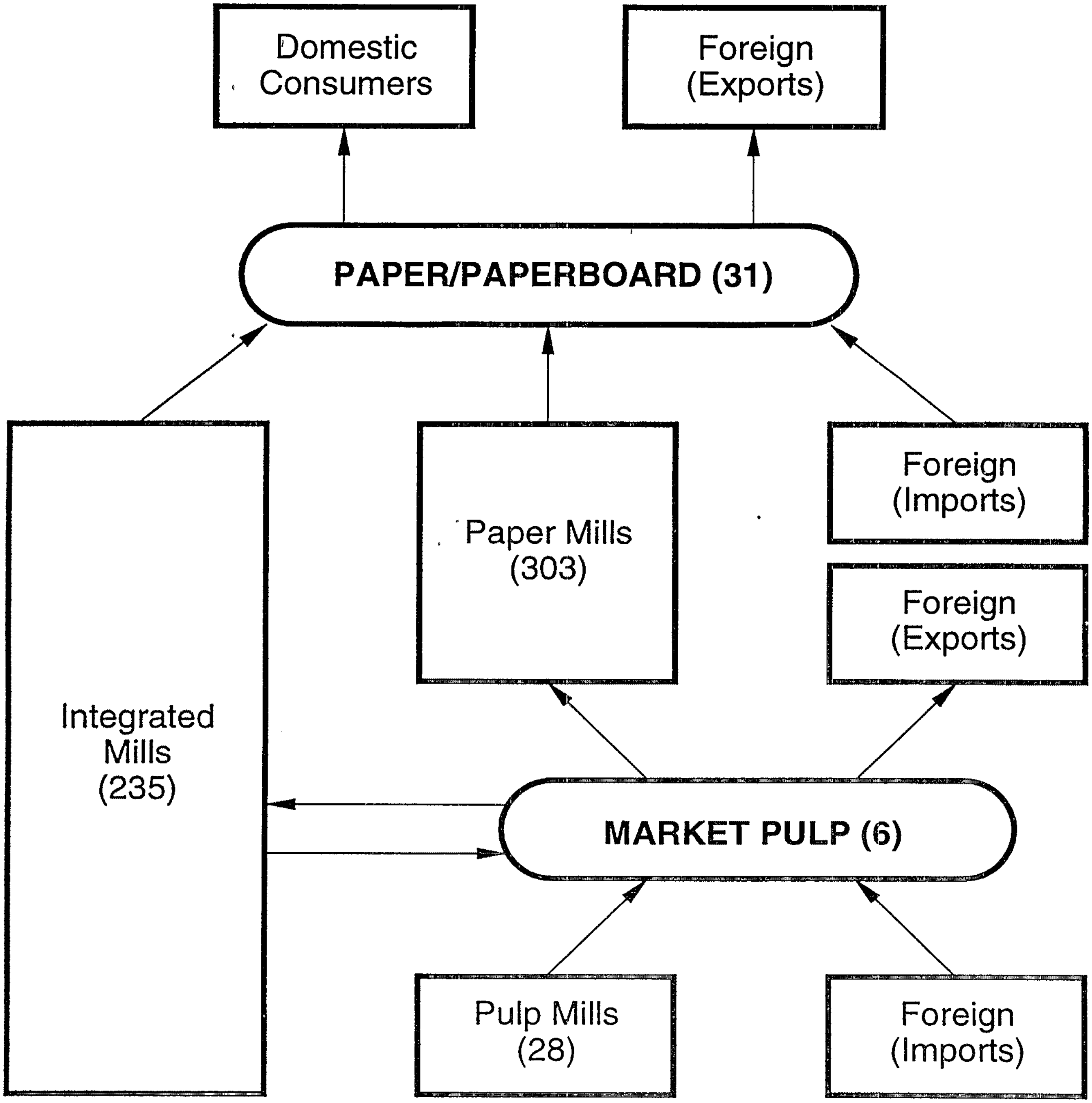


Figure 3-12. Interactions between commodities and producers.

3.3.2.2 Commodities

EPA's *1990 National Census of Pulp, Paper, and Paperboard Manufacturing Facilities* identifies the 566 mills existing in 1989 that may be affected, either directly or indirectly, by the air and water pollution regulations. The detailed production data obtained from this source on each mill form the basis for characterizing the commodities included in the model. Table 3-17 lists the products with a description of each product and its product code.

The *National Census* identifies 42 product markets to analyze—33 final paper and paperboard products and 9 pulp products. However, *National Census* data on facility-level production indicate no U.S. production of either "other shipping sack" (product code 32) or "hardboard" (product code 52) in 1989. Therefore, the markets for these two product groups are not included in the model.

Although some of the pulp product categories provided by the *National Census* distinguish between bleached and unbleached pulps, not all pulp categories have this distinction. Consequently, as shown in Table 3-18, the pulp product categories were expanded to 17 to account for bleached and unbleached versions of each pulp by matching the pulp category with pulp process codes from the *National Census*. Bleached and unbleached pulps were categorized using *National Census* data on the fiber source indicated by the pulp process codes and the percentage of the fiber that is bleached and unbleached. Distinguishing the pulp products by these features—pulping process and bleaching—is particularly important because the regulations are aimed primarily at chemical pulping and bleaching. Thus, the model includes 17 pulp inputs into the production of paper and paperboard.

Some subsets of the 17 pulps described above are sold on the market (i.e., market pulps). A number of the pulp inputs are only produced at integrated facilities for in-house production of paper and paperboard products and are consequently not marketed. In addition, some of these pulps are traded in very small quantities by a small number of suppliers; therefore, data were insufficient to derive prices for some of these market pulp products. The U.S. Department of Commerce's *Current Industrial Reports: Pulp, Paper, and Board* does not contain data on value of

TABLE 3-17

PULP, PAPER, AND PAPERBOARD PRODUCTS

Product (Code)[a]	Product Description
Pulp	
Special alpha and dissolving woodpulp (1)	Chemical pulp from wood and other fibers with a very high alpha cellulose content, readily adaptable for uses other than paper and paperboard making.
Sulfate-bleached (2) Sulfate-unbleached (3)	Made from an alkaline pulp manufacturing process that cooks chips in a pressure vessel using a liquor of primarily sodium sulfide and sodium hydroxide with sodium sulfate and lime being used to replenish these chemicals in recovery operations (also kraft).
Sulfite-bleached (4) Sulfite-unbleached (5)	Made from acid pulp manufacturing process that cooks chips in a pressure vessel using a liquor composed of calcium, sodium, magnesium, or ammonia salts of sulfurous acid.
Groundwood-bleached (6) Groundwood-unbleached (7)	Slurry produced by mechanically abrading fibers from barked logs through forced contact with the surface of a revolving grindstone. Used as newsprint and publication paper.
Thermomechanical-bleached (8) Thermomechanical-unbleached (9)	Pulp made by presteaming chips and reducing them into their fiber components during an initial mechanical treatment in refiners under elevated temperature and pressure. Subsequent refining done at atmospheric pressure.
Semichemical-bleached (10) Semichemical-unbleached (11)	Lower quality pulp made by cooking fibrous materials in a neutral sodium sulfite-sodium carbonate liquor followed by a final separation of the fiber using unpressurized mechanical means.
Defibrated or exploded-bleached (12) Defibrated or exploded-unbleached (13)	Pulp made by thermomechanical process in which woodchips are pretreated with a chemical, usually sodium sulfite, either prior to or during presteaming as an aid to subsequent mechanical processing in refiners.
Secondary-bleached (14) Secondary-unbleached (15)	Any type of paper- and paperboard-making fiber obtained from wastepapers and other used, reclaimable fiber sources.
Cotton and rag pulp-bleached and unbleached (16)	Pulp made from rags or cotton linters by a conventional cooking process with lime and sodium hydroxide, followed by refining and bleaching.

TABLE 3-17 (cont.)

Product (Code)[a]	Product Description
All other fiber, n.e.c. (17)	Pulps other than wood such as pulp of fibrous vegetable material (e.g., straw, reed, bagasse, bamboo, etc.); or synthetic and semi-synthetic sources (e.g., glass, fiberglass, rayon, nylon, combinations).
Paper	
Newsprint (20)	Light, inexpensive grade made largely from mechanical pulps and some unbleached sulfite or other chemical pulps.
Uncoated groundwood paper (21)	A higher grade than newsprint that is smoother and brighter and used in newspaper inserts, catalogs, paperback books, and directories.
Clay-coated printing and converted paper (22)	Printing and converting papers that contain a layer of coating material, such as clay or pigment, in combination with an adhesive.
Uncoated free sheet (23)	Contains no more than 10% mechanical pulps, including most grades of business paper (forms, bond, stationary, tablet, envelope, xerox, and computer paper, and cover and text grades used in printing).
Bleached bristols (24)	High-quality cardboards used for products such as index tags, cards, file folders, and postcards.
Cotton fiber writing paper and thin paper (25)	Papers in which cotton or other nonwood fibers comprise 25% or more of the total (e.g., bond, ledget, specialty papers [also, rag]).
Unbleached kraft packaging and industrial converting paper (26)	Various types of paper used for industrial or commercial purposes, such as wrapping papers, bag and sack stock, specialty papers.
Special industrial paper, except specialty packaging (27)	Special industrial papers such as photographic sensitizing paper, blotting paper, filter paper.
Tissue (28)	Light, fairly transparent, strong, absorbable, easily disposable paper, characterized by its gauze-like texture, made from mainly bleached kraft and sulfite pulps. Used for sanitary products.
Wrapping (30)	Grade of nonsanitary tissue, all M.G. and M.F. wrapping papers, treated and untreated butcher papers, and miscellaneous wrapping.

TABLE 3-17 (cont.)

Product (Code)[a]	Product Description
Shipping sack (31)	Paper made mainly from sulfate or soda, unbleached or bleached woodpulp characterized by toughness and strength, used in the manufacture of shipping sacks.
Other shipping sack (32)	Rope and combination kraft and rope shipping sack paper.
Other bag and sack (33)	All other kraft wrapping paper made mainly from sulfate or soda, used in the manufacture of grocery bags and bags other than shipping sacks.
Other bag and sack paper for conversion (34)	Used for conversion in liquor, millinery, notion, or other variety bags.
Waxing stock (35)	Packaging paper with weight over 29.4 g/m^2.
Other (36)	Other packaging and industrial converting paper such as asphalting and creping stocks, coating and laminating, gummed, twisting and spinning stocks (weight over 29.4 g/m^2).
Specialty packaging (37)	Packaging paper of weight not more than 150g/m^2.
Glassine, greaseproof, and vegetable parchment (38)	Papers made from pure chemical woodpulp or from mixtures of chemical woodpulp, cotton fiber pulp, treated by highly hydrated or hand beaten to render the resulting paper resistant to oil, grease, and water.
Paperboard	
Unbleached kraft (40)	High-strength paperboard made from sulfate pulp, usually with a naturally brown color from unbleached pulp.
Semichemical paperboard (41)	Made from semichemical pulp, mostly used for corrugating medium, which forms the inner, fluted layer of cardboard and corrugated containers.
Recycled paperboard (42)	Made from a combination of recycled fibers from various grades of paper stock, used for folding boxboard; core, can, and tube grades, corrugating medium; and gypsum linerboard.
Wet machine board (43)	Paperboard manufactured using a paper machine consisting essentially of a wire-covered cylinder rotating in a vat of pulpstock on which a mat of varying thickness is formed by drainage, such as binder's board and shoe board.

TABLE 3-17 (cont.)

Product (Code)[a]	Product Description
Construction paper (50)	Heavy paper used for watercolor and crayon artwork, made in various colors primarily from groundwood pulp.
Hardboard (51)	Paperboard made resistant to water and ink penetration by exposure to high degree of sizing treatments.
Insulating board (52)	Paperboard used for insulating electric cables.
Bleached linerboard (60)	Kraft paperboard used to line or face corrugated coreboard to form shipping boxes and various other containers.
Folding carton type board (61)	Type of boxboard made of bleached chemical woodpulp and used in the manufacture of "folding type" containers that are formed, filled, and closed by the user.
Milk carton board (62)	Special grade of bleached boxboard capable of being converted into containers for milk, cream, and other beverages.
Heavyweight cup and round nested food container (63)	Bleached paperboard used in the manufacture of cups and other nested cylindrical containers, used for hot and cold drinks and in packaging moist, liquid, and oily foods.
Plate, dish, and tray stock (64)	Bleached paperboard, hard-sized for moisture resistance and strength qualities.
Bleached paperboard for miscellaneous packaging (65)	Paperboard for miscellaneous packaging purposes such as nonfolding board for shipping cases and set-up boxboard.
Other solid bleached board (66)	Single-ply, homogeneous types of paperboards, made from the same stock throughout the sheet structure, including paperboard for moist, oily, and liquid foods.
Molded pulp products (70)	Products including fruit and vegetable packs and egg cartons.

[a]For all products termed bleached or unbleached: bleaching is the process of chemically treating fibers to reduce or remove coloring matter so that the pulp is improved in terms of whiteness or brightness; unbleached is produced without being treated with bleaching agents.

TABLE 3-18

PULP PRODUCTS, PRODUCT CODES, AND PROCESS CODES

Pulp Product	Pulp Product Code	National Census Process Code[a]
Special alpha and dissolving woodpulp	1	A, D
Sulfate-bleached	2	C, W
Sulfate-unbleached	3	C, W
Sulfite-bleached	4	B
Sulfite-unbleached	5	B
Groundwood-bleached	6	H, J
Groundwood-unbleached	7	H, J
Thermomechanical-bleached	8	G
Thermomechanical-unbleached	9	G
Semichemical-bleached	10	E
Semichemical-unbleached	11	E
Defibrated or exploded-bleached	12	I, F
Defibrated or exploded-unbleached	13	I, F
Secondary-bleached	14	K, L, M, N, O, P, R, S, T, U, Y, Z
Secondary-unbleached	15	K, L, M, N, O, P, R, S, T, U, Y, Z
Cotton and rag pulp-bleached and unbleached	16	V
All other fiber, n.e.c.	17	Q, X, SS

[a]Process codes taken from Subappendix Table AA-1.

product shipments and quantity of product shipped for a number of pulps because of disclosure concerns. Thus, the model analyzes only six market pulps for which good information was available:

- Special alpha and dissolving woodpulp
- Bleached sulfate
- Unbleached sulfate
- Bleached sulfite
- Bleached secondary fiber
- Unbleached secondary fiber

3.3.2.3 Domestic Supply of Pulp, Paper, and Paperboard

In this model, facilities are classified as either integrated or nonintegrated, and nonintegrated mills are broken down further into pulp mills and paper mills. Each type of facility has a different decision to make regarding production of pulp, paper, and paperboard, so we model the production decisions at each type of facility accordingly.

Integrated mills must determine optimal output given the market prices for all paper products they produce, which will determine the amount of internal pulp to produce. Excess supply of pulp will spillover into the market, while excess demand will cause the facility to demand market pulp. For nonintegrated paper mills, the market prices for pulp inputs and final paper and paperboard outputs will determine the optimal level of output to produce, and then, the corresponding market pulp to purchase. For pulp mills, the price of market pulp will determine the optimal supply of market pulp. The market supply of pulp is the sum of supply from all market pulp suppliers, and the market demand for pulp is the sum of demand from all market pulp demanders. The same is true for paper and paperboard products.

Mills have the ability to vary output in the face of production cost changes. To allow for mills to vary output in the face of regulatory control costs, the model uses facility-specific, upward-sloping supply curves for each product. The model employs supply functions for pulp and paper products that are derived from a generalized Leontief technology with the assumption of no substitutability across final products (i.e., cross-price elasticity of supply equal to zero for all mill outputs). The specification also restricts production to a fixed-proportion relationship between paper and pulp—that is, each unit of paper product requires a fixed number of units of pulp input. This fixed-proportions relationship implies that the firm's profit function, supply functions, and derived demand functions depend on product output price and market pulp input prices only insofar as they depend on net price. Further, we assumed that the variable proportions input combines with pulp according to a generalized Leontief technology, which is not fixed proportion.

The upward-sloping product supply curve for each facility is econometrically estimated by ordinary least squares (OLS) using facility-specific data on production from the *1990 National Census of Pulp, Paper, and Paperboard Manufacturing Facilities* and market prices obtained from U.S. Department of Commerce data. The supply curves are specified over a productive range with an upper bound given by facility production capacity and a lower bound given by the facility's minimum economically viable output level.

3.3.2.4 Incorporating Regulatory Control Costs

The starting point for assessing the impact of the regulations on the markets for pulp and paper products is to incorporate the mill-level regulatory compliance costs. The compliance costs for each mill are estimated by Agency engineers and include the total capital investment, the annual general and administrative costs, and the annual operating and maintenance costs (variable costs).

The primary challenge of incorporating regulatory control costs into the model structure is to appropriately assign variable production costs to the pulp products directly affected by the incidence of control costs. In some cases this assignment is straightforward, such as the case of bleach plant process changes or the case of bleach plant process vent controls. In these cases, the variable costs are shared by each bleached pulp product produced by the affected process. Other cases are not as straightforward, such as the case of secondary wastewater treatment controls. Because the costs of these controls are not readily attributable to any specific production area of the mill, the costs are assumed to be shared by all pulp products produced at the mill. The result of assigning variable costs to the pulp products produced by each mill is a mill-specific, per-unit production cost change for each of the 17 pulp products.

The second challenge of incorporating regulatory control costs into the model structure is to calculate the annual nonvariable cost of regulation-imposed controls. The annual nonvariable control costs are determined from the net present discounted value (NPDV) of the stream of annual cash outflows, where the cash outflows are the total capital investment and the annual general and administrative costs. The length of the stream of cash outflows corresponds to the average depreciable life of the capital investment, which is estimated as 15 years, and the costs are discounted using the facility-specific discount rate reported in the *National Census* (which averages around 12 percent). The annual nonvariable control cost is then computed by annualizing the NPDV over the lifetime of the investment at the facility-specific rate of discount. The annual nonvariable control costs enter the model at the facility level, while the per-unit variable control costs enter at the product level for all facilities affected by the regulations.

3.3.2.5 The Facility's Product-Level Supply Decisions

The production decisions at the three types of facilities—integrated paper mills, nonintegrated paper mills, and pulp mills—are affected differently by the variable costs of control (i.e., the annual O&M costs). These direct costs are borne by pulp producers, both suppliers of pulp to the market and to integrated mills that produce and consume their own pulp. Because of the direct costs of control, market pulp prices will rise, leading to indirect costs borne by nonintegrated paper mills and integrated paper mills who purchase market pulp. The nonvariable control costs do not directly affect product-level supply decisions except in the case of facility closure, where supply is reduced to zero.

For integrated mills, the variable costs of control associated with onsite production of pulp will be borne at the level of paper and paperboard production. These costs are expressed per unit of pulp and can be transmitted up to the paper product through the input ratios. Integrated mills will be indirectly affected by increases in the price of market pulp inputs. These increases in pulp prices are transmitted through the purchased input ratios. Nonintegrated paper mills may not be directly affected by the control costs, but they will be indirectly affected through the changes in the prices of market pulp inputs to paper production. Pulp mills will be directly affected by the regulatory control costs, which enter the supply decision as a net price change to pulp producers.

3.3.2.6 Facility Closure Decisions

The facility may not always find complying with the regulation feasible and thus may shut down the pulp and paper manufacturing operation because it is no longer profitable. Thus, a facility's optimal choice could be to produce zero output (i.e., close the facility). The model defines the sufficient condition for production at the mill as non-negative net earnings before interest, depreciation, and taxes (EBIDT). EBIDT is defined as the annual difference between postregulatory production revenues less postregulatory production costs, including the variable and nonvariable costs of compliance. The closure decision as defined here does not include an annualized value for the liquidation opportunity cost, which is equivalent to assuming that the opportunity cost is offset by the costs of closing the facility.

3.3.2.7 Domestic Demand For Pulp And Paper Products

Market Pulp. The market impact model does not specify an exogenous demand function for market pulps because that demand is derived from the paper supply decisions at the integrated and paper mills. Therefore, once the paper and paperboard production decisions at each mill have been made, the mill-specific, purchased input ratios for each market pulp will determine the domestic demand for each market pulp. Internal consumption of pulp is determined by mill-specific, onsite input ratios for each pulp input. These on-site input ratios also form the basis for transmitting the variable compliance costs expressed per unit of pulp produced at the mill to per-unit variable compliance costs at the level of paper and paperboard products. We derived the mill-specific, purchased input ratios for each market pulp and the mill-specific, onsite ratios for each pulp input from technical production data reported in the *National Census*. We assumed these ratios to be constant throughout the analysis, thereby restricting each mill to produce paper and paperboard products with the same combination of fiber sources, in the same relative amounts, both before and after imposing the regulations.

The model assumes the integrated mills that met all pulp input needs through onsite production in 1989 will not be active on the markets for pulp and will continue to satisfy all pulp requirements internally after imposing the regulation. Thus, these mills are neither suppliers nor demanders in the markets for pulp. However, the model does account for the interaction of those integrated facilities that were active in the pulp markets during 1989, by specifying supply relationships for market pulp suppliers, or by specifying purchased pulp input ratios for market pulp demanders.

Paper and Paperboard Products. The market impact model uses an exogenous demand function for paper and paperboard products. The function is consistent with a constant elasticity demand curve. The function was econometrically estimated, producing an elasticity of demand. The demand elasticity measures the proportional change in quantity demanded given a proportional change in price. Economic theory suggests that the elasticity is negative (i.e., a rise in price should induce a reduction in quantity demanded, all else equal). The absolute value of a product's demand elasticity measure is often compared to a benchmark value of 1. An absolute value greater (less) than 1 indicates that demand is elastic (inelastic) with respect to price.

3.3.2.8 Modeling the Foreign Sector

The importance of including a foreign sector in the economic model is highlighted by the significant level of international trade of products manufactured by facilities in the U.S. pulp and paper industry. Section Two of this report provides detailed information on the extent of foreign supply of pulp and paper products to the U.S. (imports) and foreign demand for U.S.-produced pulp and paper products (exports).

The market model specifies general functions for the foreign supply and demand for each market pulp, paper, and paperboard product. These functions incorporate estimates of the elasticities of foreign supply and foreign demand, which determine the responsiveness of foreign trade flows to changes in domestic product prices. These elasticities were numerically computed, rather than econometrically estimated, because domestic elasticity estimates are believed to understate the price responsiveness of trade flows. Where foreign trade is a relatively minor component of U.S. consumption or production, elasticities imply that regulation-induced price changes may generate large proportional changes in imports and exports. But these changes may not be so large in absolute value, given the small initial values of foreign trade. Price-taking in world markets should dampen the price effects of regulation in U.S. markets because theoretically large potential import supplies are available at the "world" price, and U.S. producers are not able to significantly raise the price of exports on world markets.

3.3.3 Determining Market Equilibria

The market impact model evaluates the supply and demand in each pulp, paper, and paperboard product market. Recall that the market supply of pulp is the sum of supply from U.S. mills plus foreign supply. In similar fashion, the market supply of paper and paperboard products is the sum of supply from all paper and paperboard producers, including foreign suppliers. Recall also that the market demand for pulp is the sum of derived demand for market pulp across all U.S. mills plus foreign demand. In similar fashion, the market demand of paper and paperboard products is the sum of demand from all paper and paperboard consumers, including foreign demand.

In the market impact model, each type of facility, integrated or nonintegrated, makes a supply decision. The model is set into motion when facilities face increased production costs due to compliance, which cause the facility-specific production responses. The cumulative effect of these responses leads to a change in the market price that all producers (affected and unaffected) and consumers face, which leads to further responses by producers (affected and unaffected) as well as consumers and thus new market prices, and so on. The new postregulatory equilibria is the result of a series of iterations between producer and consumer responses and market adjustments, until a stable market price arises where total market supply equals total market demand.

The process for determining equilibrium prices (and outputs) is modeled as a Walrasian auctioneer. The auctioneer calls out a price for each product and evaluates the reactions by all participants (producers and consumers, both foreign and domestic), comparing quantities supplied and demanded to determine the next price that will guide the market closer to equilibrium (i.e., market supply equal to market demand). The model employs an algorithm to simulate the auctioneer process and find a new equilibrium price and quantity for all 37 pulp and paper product markets simultaneously. The model is governed by decision rules that ensure the auctioneer process will converge to an equilibrium. The result of this approach is a vector of post-compliance product prices that equilibrates supply and demand for all product markets.

3.3.4 Postregulatory Impact Estimates

The market model equilibria results can be summarized as both market-level and facility-level impacts. Market-level results include adjustments in product prices, market-level production quantity changes, changes in international trade flows, and changes in aggregate economic welfare as measured by changes in consumer and producer surpluses.

Facility-level impacts include an evaluation of the pre-tax postregulatory compliance cost, product-line and facility closures, and changes in production, production costs, and EBIDT. In addition, the model computes changes in employment attributable to the changes in output at each mill. These output changes are due to product-line and facility closures as well as adjustments in production at mills that continue to operate under regulation. Workers' dislocation costs associated with industry-wide job losses are also calculated based on the one-time willingness to pay to avoid an involuntary unemployment episode.